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ABSTRACT

In this work a tentative approach is described, with the intent of an optimized insertion of the environmental contents in engineering courses, using the existing disciplines, and with a minimal, if any, increase of the disciplines related to environmental protection. The disciplines are firstly classified with regard to the environmental issues into four groups: (1) the fundamental ones, which can be considered as a tool for achieving a melioration or a degradation of the environment; (2) the application ones, which can be used for the melioration of the environment by controlling or correcting negative impacts; (3) the application ones, which are related to the degradation of the environment; and (4) the application ones that are specifically related to the protection of the environment. The recommended approach for insertion can be accomplished in three different routes: (1) reinforcement of the disciplines of the Group 1, including fundamental themes related with environment, such as ecology, environmental rights, etc.; (2) modification in the disciplines of Group Three, including in their programs the discussion of the possibilities of minimizing the degradation of the environment by means of primary, preventive measures; and (3) altering the disciplines of the Group Two, in order to include in their programs the subjects related to the secondary, corrective measures for environmental protection. The disciplines of the Group Four should discuss the necessary environmental contents for each engineering course that could not be given in other groups. With this approach, all the environmental contents of the engineering formation can be given without unnecessary increase of the duration of the courses, avoiding the repetition of subjects during the course. After interviewing all the professors of the engineering courses in the UFMG (Universidade Federal de Minas Gerais), it could be demonstrated that the proposed approach is feasible, and its implementation is presently being shaped for each course. (Author/YDS)

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The Insertion of Environmental Contents in the Engineering Teaching: A Tentative Approach at the UFMG – Belo Horizonte – Brazil

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Abstract- *In this work a tentative approach is described, with the intent of an optimized insertion of the environmental contents in engineering courses, using the existing disciplines, and with a minimal, if any, increase of the disciplines related to the environmental protection. The disciplines are firstly classified with regard to the environmental issues into four groups: (I) the fundamental ones, which can be considered as a tool for achieving a melioration or a degradation of the environment; (II) the application ones, which can be used for the melioration of the environment by controlling or correcting negative impacts; (III) the application ones, which are related to the degradation of the environment; and (IV) the application ones that are specifically related to the protection of the environment. The recommended approach for insertion can be accomplished in three different routes: (a) reinforcement of the disciplines of the Group I, including fundamental themes related with environment, such as ecology, environmental rights, etc. (b) modification in the disciplines of Group III, including in their programs the discussion of the possibilities of minimizing the degradation of the environment by means of primary, preventive measures; and (c) altering the disciplines of the Group II, in order to include in their programs the subjects related to the secondary, corrective measures for the environmental protection. The disciplines of the Group IV should discuss the necessary environmental contents for each engineering course, that could not be given in the other groups. With this approach all the environmental contents of the engineering formation can be given without unnecessary increase of the duration of the courses, and avoiding the repetition of subjects during the course. After interviewing all the professors of the engineering courses in the UFMG, it could be demonstrated that the proposed approach is feasible, and its implementation is presently being shaped for each course.*

Introduction

The teaching of environmental contents in the engineering courses in Brazil is mandatory since 1976. The most institutions have decided to introduce this matter in the form of an obligatory discipline for the minimal formation of the engineers, which is hold at some time in the "professional step" of the formation, that means, after the first two years of the basic formation. Usually, this discipline has the same content for all the engineering courses of the institution.

In practice this model cannot be thought of as an effective way form achieving the best results by the teaching of environmental contents, as long as we know, that the environmental standards applied to the different engineering projects are becoming more and more stringent, and the modern engineer must be able not only to foreseen the environmental consequences of his practice, but also to plan and execute the necessary measures to overcome this problems with a technological basis. Moreover, not only the planning and execution of new projects must comply with the environmental standards, but also the possibilities of success by the development of new technologies is strongly dependent upon its capability to overwhelm the environmental fragility of the old ones.

At a first glance, it can be thought that the best way to meliorate the formation of the engineers in the environmental aspects, is simply to reinforce and enlarge the scope of the already existing disciplines of environmental protection. But it can be easily demonstrated, that this is the wrong way, since the environmental issues cannot be considered in engineering as an unconstrained and self governing matter by the formation of the students. In other words, the environmental aspects in the engineering education must be intrinsically associated with the organization of the whole course, and must be able to bring the knowledge of a) assessment of the environmental consequences of the engineering applications, b) the possibilities for preventing a potential hazards with primary measures, that means, with the choice of an appropriate technology for the implementation of the project or activity, and c) the possibilities of achieving the environmental reliance with secondary measures, i.e. dimensioning and installing adequate devices, equipment or procedures for the environmental control.

Aware of this task, the "Escola de Engenharia da UFMG", in Belo Horizonte, has planned the present project for the reformulation of the form of insertion of the environmental programs in its engineering courses, as a part of the "Programa Reenge" of modernization of the engineering teaching. The work is being done by the "Departamento de Engenharia Sanitária e Ambiental", which is currently responsible for the teaching of the environmental disciplines in all the engineering courses of the UFMG.

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Objectives

The starting point of this work is the recognition of the actual situation of the contents different disciplines in an engineer course with respect to the environment. The situation can be seen in **Figure 1**. The engineering students must fulfill during the first two or three years a series of "fundamental" disciplines, here classified as of Group I, such as mathematics, physics, chemistry, and some other applied sciences as well, as for example the transport phenomena, materials science, and so on. These disciplines are, as a rule, only **indirectly** related to either an inducement of an environmental problem at the engineering practice, or to the solution of those problems. The contents of these disciplines can be regarded as a "tool", which can be used either to cause or to prevent or control an environmental damage.

In the last semesters of the course the students are confronted with the disciplines of the professional formation, i. e. the disciplines related to the exercising of the engineering. The contents of these disciplines can be related to environment in different ways. Part of them (Group II) are disciplines whose contents can be used for the control of an environmental problem: for example, the "unit operations" in the chemical engineering, which can be applied to the pollution control, the disciplines related to energy conservation and recovery in the mechanical engineering, etc. Another part (Group III) are considered as a source or as a cause of some kind of degradation of the environmental quality. These are indeed a numerous group in the engineering formation: for example, in civil engineering the building of a road, of a water reservoir, the build in of an industrial plant, etc. Finally, the Group IV of the disciplines, which are specifically related with the environmental protection.

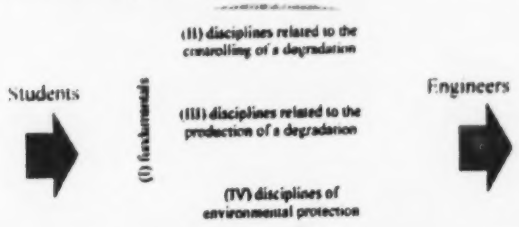
(II) disciplines related to the controlling of a degradation
Students
(I) fundamentals
(III) disciplines related to the production of a degradation
Engineers
(IV) disciplines of environmental protection

Figure 1 – Present situation of the environmental contents in the engineering teaching

In the commonly case there is little degree of relationship among these groups of disciplines, and the student receive these different information without a comprehensive integration of the relations that exist. The purpose of the present work was, firstly, the achievement of the classification of the different disciplines as related to the environment, and, in a second moment, to accomplish the integration of the contents which, as we can see in **Figure 2**. As pointed there, we identify four principal manners of integration of these disciplines, or four forms of insertion of the environmental contents: a) the reinforcement of the fundamental disciplines to include some basic scientific subjects, as for example in the fields of ecology, environmental rights, and so on. This reinforcement have the objective of better preparing of the students to understand the relation of the engineering practice with the quality of the environment in its multiple aspects, as the biological, social, and economic ones. Under b) it is intended that the disciplines, which are related to the production of some kind of degradation of environmental quality, should discuss the possibilities of reduction of this degradation in a preventive way, i.e. with primary measures by the planning, execution, and operation of engineering projects. If this is done, than the contents of the disciplines of the Group IV (environmental protection) can be attenuated. Under c), we finally see the necessity of the inclusion of the environmental protection in the form of the "end-of-pipe" control, or secondary, corrective measures. In our opinion, these contents must be given either in the disciplines of the Group II or of the Group IV, since they could be specially dedicated to the teach the planning, dimensioning, installing, and operating of the systems for pollution controlling, whereas the disciplines of the Group III are mainly related to the processes, devices, operations, or activities which primarily produce the harms.

If this concept can be put into practice, it is thought that the wholeness of the necessary subjects for the engineering formation in the environmental issues can be achieved in a comprehensive and interconnected way. Another gains of this approach are: the reinforcement of the environmental teaching could be accomplished without the increasing the number of teaching hours (the duration) of the course, and the repetition of a same subject in several disciplines during the course could be avoided.

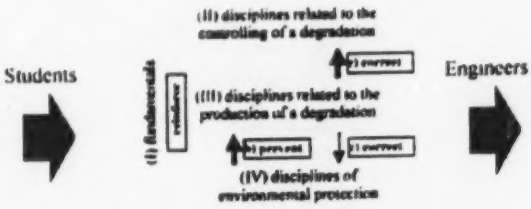
(II) disciplines related to the controlling of a degradation
Students
(I) fundamentals
reinforce
(III) disciplines related to the production of a degradation
Engineers
(IV) disciplines of environmental protection

Figure 2 – Mechanisms for optimizing the insertion of the environmental contents in the engineering teaching: a) the fundamental disciplines should be reinforced, in order to treat topics related to environmental sciences (ecology, rights, etc); b) the preventive aspects (primary measures) are taught in the disciplines that may cause a degradation of the environmental quality; c) the remedial aspects

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(secondary measures) are taught in the disciplines that deal with activities that may be used for the control of a degradation.

Methodology

For the planning and conduction of this project a group was constituted at the "Departamento de Engenharia Sanitária e Ambiental", composed of three professors, and a working group composed of one engineer and two students was engaged. The development of this work was preceded by the collection and organization of the official documentation of all the six existing engineering courses at the UFMG: chemical engineering, civil engineering, electric engineering, mechanical engineering, metallurgical engineering, and mining engineering. The arrangement of the courses, the programs of each discipline, and so on, were collected and analyzed. In the following the work has been executed in three steps:

- **1ST STEP: INTERVIEW.** In this phase the principal goal was to achieve the information concerning the nature of the relation of each discipline with the environment, as pointed above. An application form (Appendix A) was developed, tested, and thereafter was answered by each professor of the Escola de Engenharia under personal contact with the engaged students. In the period between August and December 1996 a total of 223 professors, encompassing 279 disciplines, were interviewed, as can be seen in the following table. The results of the interviews were feed to a specially developed Databank using the "MS-Access", from which the consolidated results in form of tables, diagrams, and forms could be extracted for the following steps.

Table 1 – Distribution of the interviews in the engineering courses

Course	Abbreviated	Number of Professors	Number of disciplines
Chemical	che	28	30
Mining	min	30	36
Metallurgical	met	30	37
Mechanical	mee	37	61
Civil	civ	71	86
Basic Sciences	bas	27	29
TOTAL	tot	223	279

- **2ND STEP: DISCUSSION.** This stage is still in course and will be concluded soon, and comprehend the discussion of any individual modification in each discipline, that are thought to be recommendable for achieving the optimized insertion of the environmental contents at the engineering education. The discussion process is carried out with the participation of each responsible professor individually, and the results for each course will be collectively appreciated before officially proposed. At the end of this phase all the proposed alterations in each discipline will be detailed and submitted to the advisory board ("colegiados").
- **3RD STEP: IMPLEMENTATION.** After the approval of the modifications, the implementation will deserve further work, including the familiarization of the professors with the new contents of his disciplines, and the relation between his discipline and the other ones in the field of environment. The training of the professors is also planned, and will be made as necessary. A mechanism for the continuously monitoring of the achieved results will be necessary, and the proposed alterations can be revised as needed.

Discussion of the Partial Results

In the following, we will present and discuss the most important results of the first step of the work (interview), which will be presented in form of diagrams that contain the frequency of the answer given to different questions. In each diagram the answer of professors for five different engineering courses[1] are presented separately from the basic sciences (which are held by professors of other departments of the University such as Chemistry, Mathematics, etc.). The frequency of the answer for the wholeness of the interviewed professors will also be given. Only the most significant questions will be discussed here.

[1] The sixty engineering courses (electrical engineering) were excluded of this stage, since the curriculum of this course is being fully modified in an innovative way. The insertion of the environmental contents will be made regarding the new conception of the course, and an interview of the professors concerning the old curriculum was considered unnecessary.

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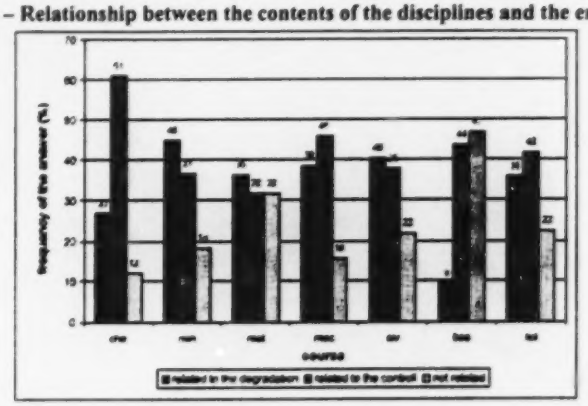
"Question 2. In which way is the content of your discipline related to the environmental issues?

a) It contributes directly or indirectly to a degradation of the environmental quality

b) It contributes directly or indirectly to the control of a degradation of the environmental quality

c) *It is not related"*

Diagram 1 – Relationship between the contents of the disciplines and the environment



The answer of this question is the most important for distinguish the relationship between the discipline and the environment. It can be seen that the chemical engineering is the course where the most portions of the disciplines can be used for the controlling of an environmental degradation, circa 60 %. In the mechanical engineering can be also observed, that there is a major part of the disciplines related to environmental protection, but this tendency is lesser preeminent. By the courses of metallurgical, mining, and civil engineering it is observed, that the number of disciplines related to the inducement and to the control of degradation achieve similar levels, but first ones are slightly dominant. As expected, the disciplines of the basic sciences are not directly related neither to the inducement nor to the control of the degradation, they are rather a "tool", that can be used for both these purposes. As a whole, the engineering courses contain a slightly more elevated number of disciplines related to the control of the environmental degradation as to the inducement (42% versus 36%, respectively).

"Question No 3. If you answered "a" or "b", please indicate the fields where this relation is most applicable:

Water:	*Using (consumption of)*		*Effluent disposal*	*Treatment*
	Dam up / deviation of streams		*Groundwater Contamination*	
Air:	*Combustion*	*Use of explosives*	*Use of CFC*	*Treatment*
	Emission of exhaust gases through stacks or ducts			
	Dust fugitive emissions	*Fugitive emissions of gases or vapors*		
Soil:	*Deforesting (clearing)*		*Moving of soil*	
	Waste production or disposal		*Use of pesticides or biocides*	

Noise and vibrations

Radioactivity

Electromagnetic fields

Other (landscape, esthetical, etc)"

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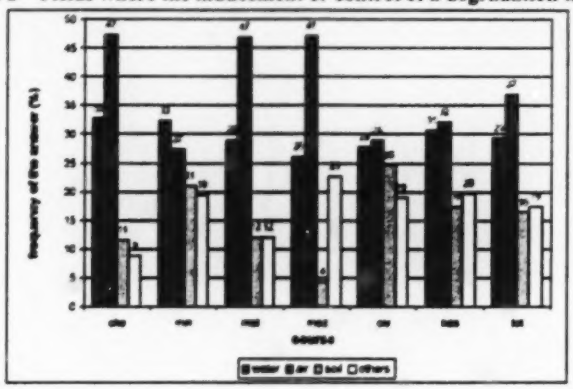
Diagram 2 – Fields where the inducement or control of a degradation take place



This question highlights the constituents of the environment which are can be most often affected (positively or negatively) by the engineering practices studied in the different disciplines of the courses. It can be seen for the wholeness of the courses, that the elements "Air" and "Water" are the more often affected. In chemical, metallurgical and mechanical engineering the field of "Air" dominate, in civil and mining engineering, the element "soil" achieves a similar degree of importance as the other ones.

"Question No. 5. In which way should be given the knowledge degradation of the environmental quality?

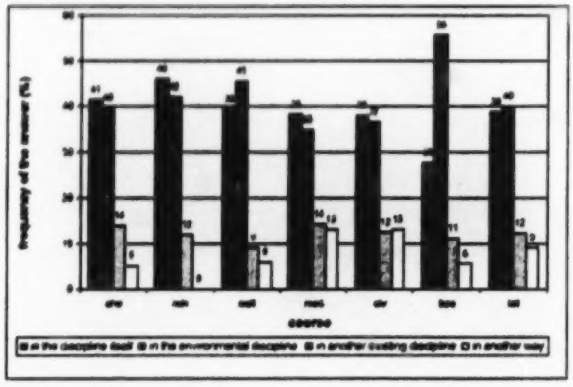
Inside the discipline itself

In a discipline that is specifically related with environmental protection and control

In another, existing discipline of the course (please point out in which one)

In another way (please point out how)"

Diagram 3 – Preferred ways for teaching the contents related with the prevention or controlling of the degradation



This question was crucial for the further development of the work. As can be seen, there are approximately the same number of professors that consider, the teaching of the ways of preventing or controlling the environmental problems can be done inside the discipline itself, as there are professors with the opinion, the best way of teaching is to deal with this contents in the disciplines that are exclusively related with the environmental protection.

By the examination of the application forms filled in, and of the personal comments written by the interviewed, it was concluded, that the majority of the professors are aware, that the issues related to the degradation of the environmental quality can be accounted for in the discipline itself, but more related to the prevention of the problems as to the correcting them. The theoretical and practical aspects of the techniques for the after-treatment of effluents,

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emissions and wastes, are beyond the scopes of these disciplines, and should be given in another disciplines. The greatest part of the professors think, the way of giving these contents are inside the existing disciplines of environmental protection.

But it can also be seen, that a considerable number of professors believe, that the engineering courses already contain other disciplines that can encompass the study of these techniques. This is indeed the possibility that is most favored as an aim for this project, as discussed in the beginning of this paper. In this way it can be achieved an adequate insertion of the environmental contents in all the disciplines: the fundamental ones and the application ones. This task is being yet accomplished for all the courses, by revising the programs of each discipline. In a further stage, the implementation
of these modifications will be achieved by the endorsement of the proposals by the official board, and by training the professors, as necessary, for the adequate insertion of the environmental contents in their disciplines.

Conclusions

In this work it could be demonstrated, that the optimizing of the teaching of environmental contents in the engineering formation can be accomplished using the existing disciplines, and with only little if any increase of the disciplines related to the environmental protection. This can be done by adequately harmonizing the different groups of disciplines, classified with regard to the environmental question into four groups: (I) the fundamental ones, which can be considered as a tool for achieving a melioration or a degradation of the environment; (II) the application ones, which can be used for the melioration of the environment by controlling or correcting negative impacts; (III) the application ones, which are related to the degradation of the environment; and (IV) the application ones that are specifically related to the protection of the environment.

For an optimized insertion of environmental issues in all the disciplines, it seems to be recommended the following approach: (a) reinforce the disciplines of the Group I, in order to include fundamental themes related with the environment, such as ecology, environmental rights, etc. (b) alter the disciplines of Group III, including in their programs the discussion of the possibilities of minimizing the degradation of the environment by means of primary, preventive measures; and (c) alter the disciplines of the Group II, in order to include in their programs the enclosing of the subjects related to the secondary, corrective measures for the environmental protection. As necessary, the disciplines of the Group IV should only discuss the absolutely necessary environmental contents for each engineering course, that cannot be given in the other groups. With this approach, the engineer could receive during his formation an comprehensive, interconnected set of knowledge in the environmental issues, without unnecessary increase of the duration of the courses, and avoiding the repetition of
subjects during the course. After an interview of all the professors in the engineering courses of the UFMG, in Belo Horizonte, it could be demonstrated that the above classification of the disciplines and the proposed approach for insertion of environmental contents are feasible. This implementation is presently being shaped for each course.

Acknowledgments: Special thanks are given to the direction of the Escola de Engenharia da UFMG (Prof. Aecio Freitas de Lira e Profa. Maria José Gazzi Salum) for the encouragement, and to the other professors of the Department which helped us in the planning and execution of the work (Profa. Monica Maria Diniz Leão e Prof. Raphael Thobias de Vasconcelos Barros). Credit must be given to the students that made the most work of interviewing and processing of the data (Eliana Moreira Lacerda and Leninha Aparecida Silvério). We are also grateful to CNPq for the personal grants given to the students and to one of us (Joana D'Arc da Silva Pinto).

Appendix A – Application Form for the Interview
REENGE – Program – Insertion of Environmental Contents

Course: .....
Department .....
Discipline: .....
Period: .....
Professor: .....
Interviewer: ..... Date: .....

1. How many times and with which regularity have you hold this discipline?

€ 1 to 3 € 4 to 9 € 10 or more € Regularly € Not Regularly

2. In which way is the content of your discipline related to the environmental issues?

a) It contributes directly or indirectly to a degradation of the environmental quality
b) It contributes directly or indirectly to the control of a degradation of the environmental quality
c) It is not related

3. If you answered "a" or "b", please indicate the fields where this relation is most applicable:

Water: € Using (consumption of) • Effluent disposal • Treatment
• Dam up / deviation of streams • Groundwater contamination
Air: € Combustion • Use of explosives • Use of CFC • Treatment
• Emission of exhaust gases through stacks or ducts
• Dust fugitive emissions • Fugitive emissions of gases or vapors
Soil: € Deforesting (clearing) • Moving of soil
• Waste production or disposal • Use of pesticides or biocides
€ Noise and vibrations
€ Radioactivity
€ electromagnetic fields
• Other (landscape, esthetical, etc)

4. Of the following topics, select the ones that are important for the minimization of the mentioned degradation of the environmental quality

• Energy: sources (substitution), quality of combustibles, conservation of energy
• Raw materials / materials: substitution, economy of the use, recycling
• Productive / Constructive Processes: substitution, operational control
• Social and legal factors: education, legislation, normalization, etc

5. In which way should be given the knowledge that is necessary to control the degradation of the environmental quality?

• Inside the discipline itself
• In a discipline that is specifically related with environmental protection and control
• In another, existing discipline of the course (please point out in which one)
• In another way (please point out how)

6. Do the summary and the program of your discipline comprise adequately the environmental issues?

• Yes • No

7. If you answered no, please specify the alterations you consider necessary on a separate piece of paper

8. Please point out the main learn material used in your discipline:

• Book (specify) • Personal notes • Others

9. Does the used learn material comprise adequately the environmental issues?

• Yes • No

10. Do you think it is necessary to ameliorate the capability of the professor with regards to the environmental issues?

• Yes • No

11. If you answered "yes", please mention in which fields this capability should be improved:

• On the environmental themes related with the discipline
• On generic environmental themes

12. Additional Remarks

Signature of the professor